CEMENT

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CEMENT MANUFACTURE

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Dry Process versus Wet Process in Portland Cement Manufacture.

A CRITICAL REVIEW.

ENGLAND is the home of the wet process of Portland cement manufacture, and possibly 90 or even 95 per cent. of the total produced in this country is made by the wet process. The United States has become the home of the dry process, and probably 90 per cent. of the total manufactured there is produced by the dry process. The greater percentage of the English product is manufactured from soft raw materials ; the greater percentage of the U.S.A. product is manufactured from hard raw materials. Whichever process is adopted, the object should be to obtain a product of the highest possible class at the lowest economic cost.

In considering the chemical aspect of the subject, it must be remembered that the prepared raw material should (1) have a consistently uniform carbonate content, (2) be very finely ground, (3) be subjected to prolonged soaking at high temperature (it is still uncertain how long is necessary), and (4) be clinkered. If these conditions are completely met and the finished product is equally finely ground, it does not appear to matter which process of manufacture is adopted.

In considering the various factors, it will be appreciated that as a liquid mixes more readily and more nearly perfectly than a ground solid, however fine the latter may be, the desideratum referred to under (1) would appear to be more difficult to obtain under dry conditions than under wet conditions. Recently applied methods (in U.S.A.) of extracting ground fines from silos and returning to the same or other silos by means of the Fuller-Kenyon pump appear to have completely, or at any rate, almost, eliminated this difficulty, and the risk of a " poor mix " is now but little more likely under dry process conditions than under wet process conditions.

Taking the two processes in sequence, the following stages refer to the successive steps and processes through which the raw material passes until clinker is produced.

The wet process is as follows—Crushing ; fine grinding (wet) or washing the mixed raw materials to a very low residue on the 1/180 (or 1/200) mesh sieve, with a moisture content of 34 per cent. to 42 per cent. (the amount of moisture will vary with the natural characteristics of the raw materials) ; heating ; evaporating the moisture ; decarbonating at a high temperature ; clinkering ; and cooling.

The sequence of the dry process is—Crushing ; and/or preliminary grinding the (separate) raw materials, drying ; passing to the respective hoppers ; extracting ; proportional weighing, mixing, and finish grinding (dry) passing again to hoppers ; extracting and returning by pumping to the mixing or kiln supply hopper ; heating ; decarbonating at high temperature ; clinkering and cooling as before.

When the raw material is of the soft type, the power required for raw material preparation will be similar, whichever process be adopted ; the actual power figure may be of the order of 6 to 8 B.H.P. per ton of raw material. When the raw material is of the hard (limestone) type, the power required will be considerably higher under wet grinding conditions than under dry grinding conditions. In the former it may be of the order of 35 to 45 B.H.P. per ton, and in the latter 20 to 25 B.H.P. per ton. R.M. in each case.

It appears best to review the various factors which are common to both processes and consider what influence the process of manufacture would have upon them.

Raw Materials.

Where raw materials are of the soft class and heavily saturated with moisture it is reasonable to assume that they lend themselves best to wet process treatment, as the original moisture can be taken advantage of and the added moisture would be less. Conversely, if damp material were treated in the dry process, considerable expenditure of fuel would prove necessary for drying out the moisture. For the same reason, where the raw material is of a hard nature and the original moisture content very low, other things being equal this raw material would in all probability lend itself best to dry process treatment.

Deliberately to mix a considerable quantity of water with raw material and then use expensive fuel to eliminate it appears to lack an understanding of ordinary scientific procedure.

Location.

If the works be located near or in a residential neighbourhood, or where the natural beauty of the countryside must not be marred, it will be necessary to keep atmospheric pollution as low as possible. The wet process appears to satisfy this condition best. It is realised that many experiments are being conducted and a wealth of experience obtained in dust precipitation by the electrical and other processes, but the electrical process is very costly and has hardly yet arrived at the stage when it may be regarded as an economic success. The next five years will in all probability see a marked advance in this direction.

Power.

The cost of power should be considered in relation to the process to be adopted. In both processes a large quantity of heat will be emitted with the kiln gases, but the greatest weight will be from the wet unit ; a fair exit temperature would be 750 deg. F., though this will depend upon the length of the kiln and the unit rating at which it is operated. The dry-process kiln is unable to utilise the low-grade heat as fully as the wet-process kiln, and the temperature of its gases may be, say, 1200 deg. F. (this may be a little lower, but it could be considerably

higher); this temperature also depends upon the length of the kiln and its unit rating.

If power is purchasable at a low figure it would hardly prove economical to use waste gas at a temperature of 750 deg. F. Exit gases at 1200 deg. F. in the dry-process plant, however, would probably show an excellent return in a waste-heat boiler installation. (See also data under "Fuel.") Power, cheap power, and power in large quantities have become a necessity in a modern plant.

Fuel.

A considerable difference exists between the fuel consumption under the two processes. Under wet-process conditions a fair figure for kiln requirements may be assessed at 30 per cent. or possibly 28 per cent. of the weight of clinker produced. Under dry-process conditions this figure can be reduced to 21 per cent. or possibly 20 per cent. of the weight of the clinker produced.

If waste-heat boilers were installed in conjunction with the dry process the difference in the total fuel would be considerable. In the following two typical cases the assumptions made indicate the difference in fuel shown at the end of the table:

	Wet.	Dry.
Kiln Fuel	28 per cent.	21 per cent.
Equal to (lbs. per ton) . . .	628	470
Power for Manufacture—		
(Elec.) Units per ton . . .	100	90
Power Produced by Waste Heat Boiler		
(Elec. Units)	—	50
Power produced from Fuel . .	100	40
Power Fuel at 2½ lb. per unit . .	250	100
TOTAL FUEL PER TON CLINKER .	878	570
=	39 per cent.	25·5 per cent.

The difference between 39 per cent. and 25·5 per cent. with fuel at 20*s.* per ton is equivalent to 2*s.* 9*d.* per ton of cement produced.

In reviewing and considering the information and data now available and examining the results obtained in recent experience, there appears to be no reason why the dry-process type of plant should not be adopted unless any of the factors mentioned prohibit it.

Proposed New American Cement Factory.

IT is reported that a contract has been signed between the Commonwealth of Kentucky and Messrs. F. B. Drew (of McAllister, Okla.), Leigh Hunt (of New York City), and Robert Hunt (of Kansas City, Mo.), whereby they will erect a $1,750,000 cement plant in Kentucky. The plant is to have a capacity of 4,000 bbl. of cement a day. The State has contracted to purchase 75 per cent. of its cement from the new plant during the next two years.

Modern Cement Manufacture.

We have received the following from a well-known authority on Portland cement manufacture, who is actively engaged on the production side of one of the largest British cement manufacturers:

Sir,—The article by your distinguished contributor, Mr. D. B. Butler, in the September number, raises some controversial questions which call for comment from one who has had the opportunity of studying cement from the practical side of its manufacture and application.

Overburning of Cement.

In his article Mr. Butler states that "Portland cement burning is carried to incipient vitrification only, and if heated beyond that point the product would be altogether spoilt and useless."

In the writer's view this is a fallacy which has arisen from two causes. First, hard-burnt cement clinker, or the so-called overburnt clinker, is difficult to bring to the state of impalpable powder which is necessary for good quality, or, in works parlance, it is difficult to "flour." By changing from ordinary burning to hard burning or semi-vitrifaction without altering the grinding process the resulting cement may have its flour content reduced by 5 per cent. or even more, although in some cases the residue on the 180 sieve may remain the same. Such a flour reduction has a marked effect upon the strength of the cement, and thus any deficiency in this connection has been erroneously attributed to the state of the clinker instead of to the failure to adjust the grinding process to meet the changed condition of the clinker.

The other reason for the fallacy is that the so-called overburned clinker is frequently not of normal composition, but is clinker adulterated with coal ash or firebrick; or in some cases it is the product of burning a low-limed slurry which has inadvertently entered the kiln. Clinker which is low-limed through contamination with an excessive amount of fuel ash, or with firebrick lining from the kiln, or through an error in the mixing of the raw materials, becomes semi-fused *at the same temperature* at which a normal clinker is properly burnt. The cement produced by such clinker is inevitably low in strength because it is deficient in lime content, and not because of its degree of burning.

The writer has frequently been handed specimens of vitreous clinker, and especially from fixed kilns, alleged to be the useless products of overburning which on analysis have proved to contain less than 60 per cent. of lime. Further, on theoretical grounds there is no evidence available from the synthetical research work that has been done in the United States and elsewhere that the primary cementitious compounds are decomposed to such an extent as to be "altogether spoilt and useless" by any temperatures up to the fusing point of cement. Is there any evidence that a cement clinker of normal composition ground to contain a proper proportion of flour can be overburnt and become deficient in quality?

False Setting Times.

Mr. Butler calls attention to the phenomenon, occasionally observed with very finely-ground cement, known in testing laboratories as "false set," which means the stiffening of cement paste even to the extent of initial set (as observed

by the Vicat needle) when the mixing of the cement and water is done very quickly. An example is given of a cement showing an initial set of seven minutes and a final set of twenty-five minutes when mixed for two minutes, but when the mixing occupies three or four minutes the setting time is prolonged to 105 minutes initial and four hours final. Mr. Butler supports the view that the setting times obtained from a short mixing should be accepted, and suggests there may be some danger of loss of strength and workability of concrete when the quick-setting times are disregarded in favour of those obtained by longer mixing.

Upon this matter, however, there is much practical evidence to support a contrary opinion. In the first place, the briquettes made for cement testing, and more especially the sand briquettes and compression cubes, occupy longer in the moulding than two minutes, so that the actual strength tests recorded in the laboratory relate to the cement which has been disturbed after the time when the stiffening, or false set, mentioned in the article has commenced. If these strength tests are deficient the cement stands self-condemned, but, if not, then there is evidence that the peculiar setting behaviour is of no importance.

Second, it is necessary to remember that the Vicat needle setting-time test described in the British Standard Specification for Portland Cement measures nothing more than rate of stiffening of the cement paste, and does not reveal the commencement and ending of the real chemical action of setting. There are probably few testers who believe that an initial set of, say, two hours, means the cement has not commenced to set before that period. What the test actually does convey is that concrete made with such cement is likely to remain plastic and workable for two hours. Hence, if there is a stiffening of the cement paste, as recorded by Mr. Butler, it does not imply that the setting of the cement will be disturbed by ignoring it, any more than the present practice of interpreting the initial set.

In the view of the present writer the stiffening that sometimes occurs a short time after the rapid mixing of finely-ground cements is merely the absorption of free water from the cement paste by the fine particles. Obviously fine cement takes up more water during the first few minutes than coarse cement; such absorption, adsorption, or chemical combination of and with water (whatever it may be) is not instantaneous, and therefore the cement and water must be kept in agitation for a minute or two longer with fine cement. If this is not done, the removal of water takes place after a short mixing is complete and causes a stiffening which is, however, not the commencement of setting.

Cement Fineness.

In his remarks on rapid-hardening Portland cements Mr. Butler expresses surprise that the Belgian specification permits a residue of 10 per cent. on a sieve of 180 meshes to the linear inch. But why should a cement specification be concerned with minute details of fineness? Should not the cement manufacturer be allowed to make rapid-hardening cement by whatever means he choose, so long as he complies with the requirements for strength and stability? If rapid hardening and high strength can be obtained by some means other than ultra-fine grinding there seems no need to compel the manufacturer to incur further expense by ultra-fine grinding. Admittedly very coarse grit is undesirable, but the limit of 1 per cent. residue on the 76 sieve is a sufficient safe-

guard in this connection. Mr. Butler suggests that a British Standard Specification is needed for rapid-hardening Portland cement, but the quality of the material on the market is developing so rapidly from one year to another that it is doubtful whether the time is ripe for such a specification until there is a nearer approach to finality in strength.

An Appreciation.

We have received the following from Mr. Henry Pooley, Jun., B.Sc., A.M.Inst.C.E., A.M.I.Mech.E., F.G.S. :—

"SIR,—Will you allow me to say how pleased I am to see the publication of a journal in this country dealing with cement and cement manufacture ?

"Writing as one who is deeply interested in the latest and best methods of cement manufacture, I feel sure that the many directly connected with the industry in this country will agree that *Cement and Cement Manufacture* should supply a want which has long been felt for a British journal on the subject.

"Furthermore, the numerous cement factories which have now been established in various parts of the British Empire so far have been obliged to depend mainly upon American journals for their news about cement making. I do not for a moment wish to decry these American productions in any way, for some exceedingly interesting and valuable articles have appeared in them from time to time, but I feel sure that the British cement confraternity in various parts of the world will welcome a British journal with open arms. It will be of more interest for them to know what is taking place at Home, especially as the Portland cement manufactured in Great Britain is second to none. Such quality is only maintained by improvements and refinements in manufacturing methods, and over-seas British makers cannot fail to be vitally interested in a record of this."

Notes from Abroad.

Polish-Hungarian Sales Agreement.

WE understand Poland and Hungary have concluded a non-violation agreement for cement in respect of their home markets.

Sales Agreement between Austria and Hungary.

It is stated that an agreement has been reached between Hungary and Austria whereby Austria will cease exporting to Hungary and the latter country will limit her exports to Austria.

New Belgian Cement Association.

It is stated that the "Union," "Tournai" and "Cronfestu" groups of cement manufacturers in Belgium have formed an association for the regulation of cement production and sales in the home market. An increase in the home trade price is anticipated.

German Cement Production.

The German Zement-Bund's sales figures recently published are as follows :

Jan.–June, 1927	3,270,000 tons.	June, 1927	680,000 tons.
,, 1928	3,702,000 ,,	,, 1928	763,000 ,,

Factory Extension in Austria.

The Austrian Perlmooser Zementfabrike A.C. has a re-construction programme in hand that will increase the works capacity by 70,000 to 80,000 tons per annum.

Refractory Materials in Cement Works.

By ALFRED B. SEARLE.

AMONG the many problems which cause anxiety to the manufacturer of cement, and especially to the works managers in cement plants, few are more embarrassing than those connected with refractory materials. These substances—intended to resist any heat to which they may be subjected—frequently cause annoyance and often serious losses at the most inconvenient times. A machine generally shows sign of wear long before it breaks, but whilst a firebrick or a block made of similar material may last for a year, its successor may be useless in a week!

The refractory materials used in cement works may be arranged in two groups: (*a*) those used in the boilers or in drying plants, in which the temperature is relatively low, and (*b*) those used in the hottest parts of kilns in which a temperature of 1,600 deg. C. may occasionally be attained, and in which a temperature of 1,500 deg. C. is regarded as normal.

Boiler Bricks.

The refractory materials used in the boilers, etc., consist almost exclusively of firebricks, and where the conditions are severe firebricks of a better quality than is usually employed are essential. Whilst firebrick manufacturers have made improvements in their products during the past thirty years, the tendency has been to buy "cheap" bricks regardless of the advantages to be obtained by the use of better ones. The power units in cement works are usually intended to work at a fairly high efficiency, and there is a tendency to overwork the boilers with the result that it is difficult to find firebricks which will prove durable. When the boilers are worked under normal conditions the firebricks will last far longer, and there is no need to use bricks with special properties which cost more.

At present, engineers in charge of large power units tend increasingly to accept the firebricks to which they are accustomed, and to lessen the severity of the conditions to which they are exposed by means of water-cooled walls and other devices. Air-cooling has been tried—the air being afterwards used for combustion—but the very low thermal conductivity of firebricks makes it ineffectual. Apart from this it is well to consult firebrick manufacturers as to what should be used, for most manufacturers are able to produce bricks to meet any desired conditions if they have the necessary information. When the cheapest bricks are ordered without regard to their suitability for their intended purpose it is hardly fair to blame the brick manufacturer if the bricks are not durable.

Broadly speaking, firebricks for boilers and similar furnaces should be moderately porous; uniform, but not too fine, in texture; accurate in size and shape; and with a somewhat dense and smooth face. If such bricks are laid with the thinnest possible joints they will usually render excellent service. Silica bricks can be used for this purpose, but those made of fireclay are preferable, as they are less sensitive to sudden changes in temperature.

Bricks made of special materials, such as alumina or carborundum, are too costly for ordinary use, nor is there much advantage to be derived from them in boilers. The blocks used for the flat arches which are being increasingly used for boilers require to possess different characteristics from ordinary firebricks, but as such blocks are almost invariably supplied by the patentees of the arches their characteristics need not be described here.

Kiln Bricks and Blocks.

The firebricks or specially-shaped blocks used for lining kilns call for much more serious consideration, and there is scope for much research and investigation as to the best materials to use. In the absence of sufficient data there is naturally a considerable difference of opinion as to which kind of bricks or blocks are the best, and, though no dogmatic statements are justifiable at present, certain conclusions are fairly well established.

Dealing first with refractory linings for rotary kilns, it is clear that one kind of brick is not equally suitable throughout the kiln. The conditions at the inlet end are quite different from those at the outlet, and different bricks or blocks are therefore desirable.

The end of the kiln at which the cement enters is relatively cool, but the presence of a large amount of steam makes it necessary to use a lining which is resistant to the corrosive action of water vapour and to the abrasive action of the cement mix as it falls on various parts of the lining during the rotation of the kiln. Ordinary close-textured fireclay bricks of accurate shape and laid with the thinnest possible joints are usually the best for this purpose. They may extend from near the inlet of the kiln to a point at which the temperature of the lining is about 1,200 deg. C. From this point onward it is necessary to use a material which will withstand (i) the high temperature; (ii) the corrosive action of any free lime present; (iii) the adhesion of the semi-molten clinker and the destructive effect of this material falling away; (iv) the hammering action of the cement-producing material as the kiln rotates; and (v) the corrosive action of the flame and any ash from the fuel which may be carried along with it.

A refractory material which will withstand all these adverse influences is of an extraordinary nature, and it is not surprising that serious difficulties are often experienced in maintaining a sound lining to the kilns. There is, indeed, much to be said for the practice of using a kiln of exceptionally large diameter and cooling part of it externally by water sprays, so that the clinker nearest to the kiln wall is chilled and solidified, and in effect provides a lining. The objection to this arrangement is that the chilled material falls away at irregular intervals and leaves a bare patch, which may be burned through before another mass of chilled material has had time to adhere.

The most generally suitable bricks or blocks for lining the hot zones of a rotary cement kiln are made of fireclay, though silica bricks are sometimes used in the mistaken belief that they are more refractory than those made of clay. If refractoriness alone were the only consideration there might be some support to this belief, but under the conditions prevailing in a rotary cement kiln, silica bricks are not in fact more refractory, and their sensitiveness to sudden changes in temperature, added to the ease with which the most fusible portions of the clinker penetrates them, makes them of doubtful value in most rotary kilns. Where silica bricks have succeeded best they have been covered by a fairly thick layer of chilled cement clinker which protects them and is the true lining of the kiln.

Fireclay bricks rich in alumina are the most suitable, notwithstanding the fact that Portland cement combines readily with fireclay to form a compound ($2{\cdot}5\ CaO.Al_2O_3.3SiO_2$), which is the most fusible of this group of silicates. Most

rotary kilns on the Continent are lined with bricks or blocks made of a mixture of fireclay and bauxite, the bricks containing almost equal proportions of silica and alumina, i.e. in the same proportion as in the mineral mullite. If fireclay alone is used as much as possible of it should be calcined at the highest available temperature and so converted into "grog." From this the obviously unsuitable pieces should be removed, and the remainder ground to a coarse powder and united with a suitable proportion of raw fireclay or with ball clay. The fireclay should not contain less than 30 per cent. of alumina, though some English rotary cement kilns are lined with fireclay bricks containing only 12 per cent. of alumina.

The bricks for the hot zones should be close in texture, accurate in shape, and laid with the thinnest possible joints, preferably without any mortar or cement. To ensure this they must be of a shape suitable for the kiln.

When the diameter of the kiln will permit, a ring of insulating bricks, made of kieselguhr or other diatomaceous earth, should be inserted between the lining and the shell. These bricks will not withstand a high temperature or the corrosive action of the clinker, but if they are properly protected they prevent the loss of heat which would otherwise occur.

In the cooling zone of the kiln, which is usually separate from the others, it is essential to use bricks which are not sensitive to sudden changes in temperature or liable to be disintegrated by semi-molten clinker adhering to them, cooling, and then breaking off. The most suitable bricks for this zone are those made of fireclay, especially if they are rich in "grog"; they must be sufficiently hard and close to resist the abrasive action of the clinker, yet not so dense as to spall readily.

Shaft Kilns.

The rotary kiln has many supporters, but there is an increasing tendency to realise the seriousness of its limitations and to consider that superior cement can, if due care be taken, be produced with shaft kilns. Consequently the use of shaft kilns for cement is increasing, especially abroad.

Most of the bricks required for lining shaft kilns need not be of so high a quality as those required for rotary kilns, because the temperature is not so high except in the short hottest zone. Resistance to corrosion and abrasion are the most important characteristics, and, whilst refractoriness is essential, that corresponding to Seger cone 32 is usually ample.

The difference in the conditions in rotary and shaft kilns is largely due to the fact that the rotary kiln is never full and the flames tend to travel along the lining, whereas in a shaft kiln the flame is baffled by the descending charge and exerts itself on the latter instead of on the kiln. This is beneficial in many ways, and especially in preventing undue wear of the lining.

Fireclay bricks, fairly rich in alumina and "grog," are the most suitable, and for the hottest zone, which is somewhat below the centre of the kiln, the more aluminous the bricks the more durable are they likely to be. A close and compact texture is desirable, as considerable pressure is exerted on the bricks; they should also be accurate in shape, as thick joints and irregular bricks do not last long. The bricks in the upper and lowest parts of a shaft kiln need not be so rich in alumina as those in the hottest zone, and ordinary fireclay bricks will suffice if they have not been compressed too severely during the course of manufacture. A pressure which is just sufficient to ensure the requisite accuracy

of shape produces bricks of a much better quality and durability in a cement kiln than bricks which have been subjected to a heavy pressure.

Plastic Refractory Materials.

Plastic materials—known as "cements" and also sold under various trade names—are sometimes used for repairing cement kilns. They are good for patching but not suitable for permanent work, as they have a different coefficient of expansion and do not adhere well to the brickwork. Moreover they tend to fall away unexpectedly and to affect the composition of the cement with which they become mixed.

Quality *v.* Price.

In purchasing refractory materials for cement kilns it is always better to select them on a basis of quality rather than on price. The cost of repairs is not limited to what is paid for the new bricks, but includes the cost of removing the old material and laying the new; in addition, the loss due to the kiln being out of action and the poor cement produced when it is restarted must also be taken into account.

Firebricks of all kinds are too often sold on their reputation and too seldom on their actual properties. The bricks of a certain manufacture become "fashionable" for a time and fetch high prices, whilst bricks of an equal, or even superior, quality can be obtained more cheaply from another firm. For this reason neither "make" nor price alone should be considered; the physical properties of the bricks, and to some extent their chemical composition, are the only reliable bases on which to purchase them.

Proposed New Kent Cement Works.

It is announced that the erection of a new cement works, to be the largest in Europe, is contemplated by Tilmanstone Collieries, Ltd. The new factory is to be erected near Tilmanstone, Kent.

Continental Cement.

Commenting on the importation into Great Britain of Continental cement, a United States contemporary points out that owing to its inferior quality this foreign cement is suitable only for "types of work where a low-grade cement can be satisfactorily used," and continues: "The British product is of the finest quality, and as such commands a large market abroad, in addition to the home inlet for the high quality product." It is surely an anomaly that, with the best cement in the world at their door, British cement users should buy an inferior foreign material, while the discriminating foreigner insists on the British product.

Portland Cement Manufacture.

By A. C. DAVIS, M.I.Mech.E., M.Inst.C.E.I., F.C.S.

[*This is the first of a series of articles in which Mr. A. C. Davis, Works Managing Director of the Associated Portland Cement Manufacturers, Limited, will discuss the whole subject of Portland cement manufacture. In the present article the early history of the subject is briefly outlined. Future articles will deal with the most up-to-date processes of producing high-quality modern Portland, rapid-hardening Portland, and aluminous cements. It is hoped these articles by such an eminent authority will be of the utmost value to all concerned with the industry.*]

PORTLAND cement is an active combination of silicates and aluminates of lime obtained by the preliminary grinding and mixing of the requisite quantities of lime (usually in the form of carbonate), silica, and alumina, burning the mixture to incipient vitrifaction, and grinding the resulting clinker to a fine powder with a small percentage of gypsum. With the raw materials usually employed in Portland cement manufacture small quantities of iron oxide and magnesia are invariably introduced in the manufacture as impurities.

The name of " Portland " cement, if not the material, is handed down to us from " Joseph Aspdin of Leeds, in the County of York, Bricklayer," the inventor of a cement that was first described as " Portland " cement in 1824. The derivation of the name " Portland " for an hydraulic cement was doubtless adopted to distinguish the then new cement from other similar cements used at the time for construction purposes, and long previous to Aspdin's cement it is on record that Smeaton (in 1756) stated that the cementing material he then himself made for the construction of the first Eddystone Lighthouse " would equal the best merchantable *Portland* stone in solidity and durability." Following Smeaton's discovery a patent was taken out in 1822 by Frost for what he called " British Cement."

It may then be considered most probable that in following, in 1824, with a patent applying to " An improvement in the modes of producing artificial stone and which I call ' Portland cement,' " Aspdin was simply adopting a new and suitable name for what he considered to be a building material which would be used as a substitute for Portland stone.

The history of cements is a long one—that of " Portland " cement is comparatively modern, for the past hundred years have seen its original invention in England and the product brought to its present state of perfection, while the manufacture of British Portland cement has been copied and has to-day become a staple industry the world over.

Ancient Cementing Materials.

The use of some cementing material to bind together the small stones or other materials employed in the construction of walls, and also for the purpose of giving them a smooth surface adapted to receive polychromic

or other decoration, dates from a very great antiquity. It was subsequent to the discovery of the art of brickmaking that the ancients arrived at that of burning lime. Indeed, the use of moistened clay, which was found to have a certain ductility and also to harden in drying, is certain to have preceded that of lime as a cement; for the qualities and the mode of obtaining the latter were of a nature to require long study and great experience.

The Assyrians and Babylonians appear to have employed either moistened clay or the bitumen so plentifully supplied by the springs in their countries. Some doubt, however, exists as to whether these people did ever really use a mortar. Antiquarians in relating their experiences sometimes talk of coming across bricks which were cemented together with a coarse layer of lime. In other cases it is said that between the brickwork of ancient buildings, and at irregular distances, a layer of white substance is perceptible, varying from ¼ in. to 1 in. in thickness, not unlike burnt gypsum or sulphate of lime. From the peculiarly mollified state of the bricks it is probable this white powder was nothing more than common earth, which had undergone this change by the influence of the air on the clay composing the bricks.

The Egyptians, however, certainly used lime mortar in the construction of their pyramids; chemists have given analyses of the mortar employed in the construction of the Pyramid of Cheops which show that the ancients possessed nearly as much practical knowledge of the subject as we do at the present day.

The Greeks at a very early period of their civilisation used compositions, of which lime was the base, to cover walls constructed of unburnt bricks. According to Plinius and Vitruvius the palace of Croesus, the Mausoleum, and the palace of Attalus were protected, or ornamented, in this manner. According to Strabo the walls of Tyre were built of stone set with gypsum, apparently a very common material in Asia Minor, the centre of the old Assyrian civilisation.

In Italy the first people to employ mortar in their buildings were the Etruscans. Gori, in his *Museum Etruscum*, mentions that in the tombs found near their ancient cities, such as Iguvium, Clusium, and Volterra, the structures were made with a cementitious mortar. Near Volterra also, in 1739, a cistern entirely built and lined with that material was discovered.

A branch of this nation, known as Tyrrhenians, was considered by the Greeks to have invented, or at least considerably improved, the art of masonry. The most ancient authors, such as Homer, Hesiod, Herodotus, and Thucydides, speak of them under that name, and call their walls by the word "tyrsis," instead of "Teichos," the name used by more modern authors. The word "tyrsis" is supposed to have had the same signification in the Etruscan language, and the towers erected for the purpose of fortification were also called "tyreis" by the Greeks.

The Romans, as is well known, derived all their knowledge of the arts either from the Etruscans or the Greeks. They added little to the general stock of knowledge regarding the use of limes, but Vitruvius is

the first author upon the subject whose works have descended to us. The text of this remarkable man's works show that the ancients, although they adopted a different scientific phraseology from that in fashion in the eighteenth century, knew as much of the laws regulating this branch of chemistry as the moderns of that time. For all practical purposes Vitruvius is even now as safe a guide as most of the authors who treated the subject subsequently—at least until we arrive at the researches in France of M. Vicat.

Plinius and St. Augustin occasionally refer to limes and cements; the former principally to complain of the malpractices of the builders, the latter to seek metaphysical comparisons.

On the revival of literature after the Cimmerian darkness of the Middle Ages (which it is now so much the fashion to admire), the authors who treated upon the art of building, such as Albertu, Palladio, Bullet, and Plondel, did little more than follow in the traces of Vitruvius. There was a difference of opinion, it is true, as to the quality of sand which it was most advisable to use; some new limes, some puzzolanos, terrass, and ashes, were often employed to give to certain limes the faculty of setting under water, but until about the middle of the nineteenth century no advance seems to have been made towards ascertaining the principles which regulate this branch of chemistry.

It is indeed worthy of remark that the more useful arts do not appear to be carefully studied until the practical results they are capable of producing are ascertained; then the rules drawn from such results are received implicitly for a long period, and any attempt to ascertain the laws which regulate them is regarded as useless. The human race appears to attain empirical knowledge quickly; scientific knowledge arrives at a much later period. So it was with limes; so it is with the casting and puddling of iron—a subject equally interesting.

Smeaton's Experiments.

The first serious attempt to ascertain the causes which gave some limes the power of setting under water, and which modified their rates of hardening, was made by the father of civil engineering in England, John Smeaton, in 1756.

Being at that time engaged in the construction of the first Eddystone Lighthouse, he found it necessary to have a cement capable of hardening at once in water. He therefore began a series of experiments which have been detailed in his account of the building of that great work. The results he arrived at were remarkable, not only for their practical utility but also as an illustration of the ease with which a very acute observer may stop short of the attainment of a great truth.

Smeaton found that the commonly accepted opinion in his time, namely, that the hardest lias lime stones of Aberthaw gave the best limes, was only true so far as regarded each quality considered by itself. That is to say, that of limes not fit to be used as "water cements" those made of the hardest stones were the best for certain uses in the air; but that when obtained from the hardest marble or the softest chalk such

limes were equally useless when employed under water. He found, indeed, that all the limes which could set under water were obtained from the calcination of such limestones as contained a large portion of clay in their composition.

His experiments led him to use for the important work of the Lighthouse a cement compounded of blue lias lime from Aberthaw and of puzzolano brought from Civita Vecchia, near Rome. Even at much later periods it was difficult to employ a better material than this, except that the price would ensure a preference to the Roman cement ultimately made but then unknown.

Smeaton in his records gives a table showing that all the "water limes" were obtained from limestones containing clay in chemical combination in proportions varying from $\frac{3}{14}$ to $\frac{1}{7}$, and goes on to say:—

"It remains a curious question, which I must leave to the learned naturalist and chemist, why an intermediate mixture of clay in the composition of limestone of any kind, either hard or soft, should render it capable of setting in water in a manner no pure lime I have yet seen, from any kind of stone whatsoever, has been capable of doing. It is easy to add clay in any proportion to a pure lime, but it produces no such effect; it is easy to add brick dust, either finely or coarsely powdered, to such lime in any proportion also; but this seems unattended with any other effect than what arises from other bodies becoming porous and spongy, and therefore absorbent of water as already hinted, and excepting what may reasonably be attributed to the irony particles that red brick-dust may contain. In short, I have as yet found no treatment of pure calcareous lime that rendered it more fit to set in water than it is by nature, except what is to be derived from the admixture of trass, puzzolano, and some ferruginous substance of a similar nature." . . .
"With regard to the samples of material that were constantly kept under water, they did not seem inclined to undergo any change in form, only to acquire hardness gradually, in so much that I did not doubt but to make a cement that would equal the best merchantable Portland Stone in solidity and durability."

Research in France.

The stress Smeaton laid upon the presence of the ferruginous substance led many chemists to attribute the hydraulicity of limes to the presence of the oxide of iron. Investigators such as Guyton de Morveau and Bergmann, finding oxide of manganese in the hydraulic limes they analysed, regarded it as producing the effect in question. Their researches were nearly contemporaneous with those of Smeaton.

Some thirty years afterwards De Saussure observed that the lime of Chamouni set under water, though entirely without manganese, and he, like Smeaton, attributed this faculty to the presence of clay.

In 1813, Colets Descotils, on analysing the compact marl of Senonches, which yields on calcination a lime capable of setting rapidly under water, found it contained nearly one-quarter of silex, which led him to the conclusion that the cause of the phenomenon consisted in the presence

of a large quantity of siliceous matter, disseminated in very fine particles in the tissue of the stone itself. Later, to continue with a quotation from Vicat: "The opinion of Descotils did not weaken or invalidate that of De Saussure, since clay contains generally more silex than alumina; and the two chemists agreed, moreover, in considering the oxide of manganese, if not as a useless element, at least as one which was not essential."

This was the state of the question in 1813, and it was with the intention of putting an end to all doubts upon the subject that Vicat decided to proceed synthetically, and to compose hydraulic limes entirely by burning different mixtures of common lime, slacked spontaneously with clay. The successful result of this experiment surpassed his most optimistic hopes. All the clays rich and soft to the touch gave the same results; and Vicat's experiments were repeated in Paris in 1817 with the limes of Cleys and of Champigny and the clay from Vauvres. Further experiments, by St. Leger in England and by Raucourt de Charleville in Russia, at that time also confirmed the results previously obtained by Vicat. The subsequent researches of the most eminent chemists and engineers have confirmed the theoretical opinion which guided Vicat in his experiments, with a few recent but important rectifications of detail.

John of Berlin and Fuchs of Munich, Pasley, Ansted and Way in our own country, and many experimenters in France as well as most of the scientific authors who have treated upon the subject throughout the world, have arrived at nearly the same conclusions as Vicat with respect to the causes which influence the different actions of lime.

Even with such ancient testimony it is difficult to say, however, when and where the first more modern mortars were used.

The term or name "mortar" is of Roman derivation, owing to these thoroughly practical people using a *mortarium* to secure the perfect homogeneity of the binding material. The name should therefore now be regarded in a generic sense, and alike applicable to all preparations used in binding together in structural form stones, bricks, and other building materials.

Roman Cement.

Coming to our own time it is clear that a substantial advancement in building cements occurred near the end of the eighteenth century, when Medina cement and Roman cement were introduced. Patents for this latter material, which was more generally employed, are described as applicable to the manufacture of a "Certain Cement or Terras (trass) to be used in Aquatic and other Buildings and Stucco Work."

Roman cement consisted of "reducing to powder certain *burnt* stones or argillaceous productions called 'noddles' of clay, and using that powder with water so as to form a mortar or cement stronger and harder than any mortar or cement now prepared by artificial means." The nodules of clay were described as "certain stones of clay or concretions of clay containing veins of calcareous matter having frequently but not always water in the centre, the cavity of which is covered with small crystals

of the above calcareous matter and the noddles agreeing very nearly in colour with the colour of the bed of clay in or near which they are found." With " two measures of water and five measures of the powder thus described," Parker, the inventor of Roman cement in 1796, says his cement is then made " and will set or become indurated either in ten or twenty minutes after the operation has ceased either in or out of water." He observes, in conclusion, " the less water is used the better, and the sooner the mortar or cement is used after being made the stronger and the more durable it will be."

Contrary to the practice hitherto obtaining—and adopted by Smeaton —of only burning the raw materials sufficiently to drive off the carbonic acid gas and then reducing to powder by slaking with water, the "noddles of clay " for the manufacture of Roman cement were burnt with " a heat nearly sufficient to vitrify them," and the burnt material was then reduced to a powder by any mechanical or other operation.

" Water Cement."

Coming to more modern times, it was several decades before experimenters in making a new cement to supersede Roman cement could arrive at the point that mixtures of lime and clay or chalk and clay in certain proportions, if only calcined in a kiln (deriv. Latin, *Calcis* = lime) produced what we should now term hydraulic lime—but which the originators termed " water cement "—and yet by increasing the heat in the kiln so as to produce in the raw materials a state of incipient vitrifaction (deriv. Latin, *incipere* = to begin ; *Vitrum* = glass) a Portland cement as we know it to-day could readily have been produced. Suffice it to say that, starting with the notion of imitating Roman cement, early inventors arrived at the idea that when chalk and clay were mixed and burned an hydraulic material was produced. It is on record that in the beginning of the industry all good clinker produced by incipient vitrifaction was rejected—to-day this is the only material used for grinding into cement.

Early Nineteenth-Century Manufacture.

But even the invention of a ground hydraulic lime in those days was received with acclamation as a new and valuable cement for construction purposes to supersede the Roman cement used at the beginning of the nineteenth century, and there evidently must have been a variety of qualities of this lime on the market owing to the prevailing uncertainty as to its actual constituents and manufacture. It is recorded, for instance, that long after Smeaton's discovery of an hydraulic lime in 1756, and Roman cement subsequently, the renowned London civil engineer, Sir I. K. Brunel, changed over from the Roman cement he had previously used on his important civil engineering works to the new " Portland cement " invented by Aspdin in 1824, and he paid heavily in price for the new product with which to finish the construction of one of the first tunnels under the Thames in 1838.

Although Frost, in 1822, patented and produced what seemed to be a ground hydraulic lime (because he merely calcined his mixed raw materials), and which he termed " British cement," yet Aspdin followed suit two years later with a similar material, but in a less exact way according to his patent, and again only calcined his raw material mixture, but which he happily called " Portland cement," and this was the material Brunel preferred. Hence to-day's name for what was apparently a different product from that which had been marketed in earlier times.

As to whether or not during the practical experience of those two originators the burning of similar raw materials to those produced by Frost and Aspdin was secretly changed, or increased from mere calcining to a heat involving incipient vitrifaction, which is essential for the manufacture of Portland cement as we know it to-day, history does not relate.

So the would-be historian, in divining the exact date of the invention of Portland cement, can only arrive at the fact that from what records can be obtained Aspdin certainly was the inventor of the name of " Portland cement " if nothing else, and so we live on his heritage ! It may quite well be supposed that Aspdin actually carried out the manufacture of Portland cement secretly and without disclosing its precise manufacture in his patent ; but this is mere conjecture, and both Frost and Aspdin may yet only have manufactured the material as their patents show it to be, namely, an improved and ground hydraulic lime.

Previous to and during this period, in the early part of the nineteenth century, quite a number of works for the manufacture of different cementing materials sprang up, and there were made a Roman cement by Parker at Northfleet in Kent for general building purposes, a " British cement " by Frost at Swanscombe, in Kent, a " Portland cement " (as he termed it) by Aspdin at Wakefield, and the same product by Aspdin's son at Gateshead ; while similar and other cements were made by the firm of Francis & White, who had a business as marble merchants at Nine Elms, near Vauxhall, London. The firm of Francis & White dissolved in 1827, and in that year John Bazley White took over Frost's works at Swanscombe in Kent for the manufacture of Frost's and Roman cement.

But as to the date of the commencement of the manufacture of the material called Portland cement as we understand it one hundred years afterwards, there is less definite evidence. Indeed, from a search of the Patent Office files it can be said that there is no specific inventor recorded of the manufacture of to-day's Portland cement, or in principle closely resembling or actually as Portland cement is constituted ; and while it is true that the name " Portland " cement is recorded by Aspdin for a cement possibly differing in character from that previously used in his time (and differing also in constitution from the Portland cement of to-day), yet the historian can only suspect that the actual initial introduction of to-day's Portland cement was evolved rather than invented at a date much later than Aspdin's patent.

The material introduced by Aspdin as Portland cement and the

materials which developed from its introduction evidently continued to be sold under the generic name, and, whether as a result of experiment or accident afterwards, one cannot go further than state that it was approximately from the materials, but not by the identical process, used by Frost to make his "British cement" in 1822 and by Aspdin for his "Portland cement" of 1824, that Portland cement now reigns supreme.

Since these inventions followed closely on the manufacture and marketing of Roman cement it is evident that in the invention of this new cement the danger of overburning in the manufacture of Roman cement was present to the minds of Frost and Aspdin, for any of the overburnt septaria was useless. The required heat was just enough to reduce the weight of the raw materials to a minimum, and if the temperature of the kiln exceeded what was necessary to produce that result then the Roman cement product was unmarketable.

It is from Messrs. White's factory at Swanscombe that the first actual and clear evidence comes to us that the hitherto only calcined raw materials came to be "burned with unusually strong heat until the mass was nearly vitrified," and the claimant of this process was the manager of Messrs. White & Sons, then I. C. Johnson. We have the definite claim of Johnson to guide us approximately on this point, and as he joined the firm of White & Sons in his sixteenth year it was probably some years after his entry into cement manufacture in 1827 (possibly 1845) that he produced Portland cement, as we to-day understand the material, in contradistinction to the invention of what we now call ground hydraulic lime, once termed by Aspdin "Portland" cement—and which may, of course, well have been the "Portland cement" of Aspdin's day, but not that of our own.

So the evidence is produced of the new cementing material—similar to ground hydraulic lime as we know it—having been invented first by Smeaton, then by Frost in 1822 and called by him "British cement," followed by Aspdin in 1824 with his specification for "Portland cement"; yet all were a more or less similarly constructed material—both Frost and Aspdin having the published evidence before them of Smeaton's discovery in 1756 of a "cement that would equal the best merchantable Portland stone in solidity and durability."

Finally we have the claims (but not the patent) of I. C. Johnson, who at Frost's old factory at Swanscombe some time after the year 1840 produced for J. B. White & Sons (owners of the factory at that time) the early Portland cement which still stands to-day as a monument—or many of them—of deserved fame. The Swanscombe Works to-day exist as one of the largest Portland cement factories in Europe, with an output capacity of 400,000 tons of Portland cement per annum.

As against all this evidence an eminent civil engineer (G. R. Burnell) in 1874 stated that: "Portland cement, as it is very absurdly called, is in fact nothing but an artificial hydraulic lime, but which resists the effects of salt water admirably if we may judge from so short an experience of eight or nine years."

White's Portland cement, however, soon began to be demanded in

large markets all over the world, while at home the experiments of the late John Grant, then Engineer of the Metropolitan Board of Works, in connection with the London drainage scheme of 1859 gave an impetus to the use of Portland cement, with the result that many new factories sprang up and originated a British industry which has never flagged to this day.

While referring to examples of ancient cementing agents one is tempted to contrast the position of modern Portland cement, which penetrates to every accessible quarter of the globe where engineering science demands its aid. From Russia to India in the Old World to the North and South Americas of the New, Portland cement is an article of universal currency and an absolute necessity.

The Port of London, attracting the commerce of the world to its docks and river, naturally assisted in the establishment of a belief that Portland cement was indigenous to its neighbourhood and could only be produced by a combination of the chalks and clays found on the banks and shores of the river Thames and its affluent the Medway. In France and Germany, however, large works came into existence not long after Britain opened up their markets, and it may be said that London, Boulogne, and Stettin respectively represented the chief centres of this industry in these three home countries in the first quarter of a century of its invention. To-day the industry grows apace the world over.

(*To be continued.*)

Notes from Abroad.

New Works in Czecho-Slovakia.

The Silleiner-Ledecer Portlandzementfabriken A.C. proposes to build another cement works in Slovakia. This will be their third plant.

Cement Imports into Lithuania.

During the current year competition in Lithuania seems to have become stronger, Poland, Germany, Esthonia, Russia, Sweden and Belgium endeavouring to participate in the trade. There is a sales arrangement between Poland, Scandinavia, Germany and the Baltic States. Imports were as follows:

1926	30,637 tons.
1927	44,501 ,,

New Syrian Cement Company.

A company under the title of "Chaux and Ciments de Levant" has been formed at Beirut, Syria, financed by a local and a French bank. The capital is 20 million francs (£158,000) and works with an annual production of 60,000 tons are to be built in the neighbourhood of Beirut by September, 1929.

Australian Cement Works Extensions.

We understand that the plant of the Goliath Portland Cement Co. of Australia (which is taking over the Tasmanian Cement Co., Railton, as a going concern) is to be increased by 65,000 tons to 110,000 tons capacity per annum. The capital is £600,000. The disposal of the whole of the output has been arranged for the ensuing seven years, and Messrs. Dorman, Long have agreed to act as managers for the next five years. Cement from this plant is still being supplied to the Sydney Harbour Bridge contract.

The Largest European Cement Works.

BEVANS WORKS, NORTHFLEET.

(Continued).

Electrical Equipment.

THROUGHOUT the factory the switchgear and the distribution system have been so arranged that the supply to the different processes of manufacture is controlled from the two sub-stations, one at the washmill and the other at the main works. This also permits of the metering of the unit consumption of each section from these two main points. The factory load is 6,000 K.W.; as a result the electrical stresses on switch and control gear when operating under short-circuiting conditions are heavy, but these are considerably reduced by the cable system adopted.

For the washmill sub-station the basement of one of the two main motor-houses has been utilised. The position is at the centre of the load dealt with, and has resulted in an economical lay-out of the feeder and distribution cables. The sub-station is equipped with a 3,000-volt switchboard, one 750 K.V.A. 3,000/500 V. transformer, a 500 volt switchboard, and a 20 K.V.A. 500/110 V. lighting transformer with switchgear.

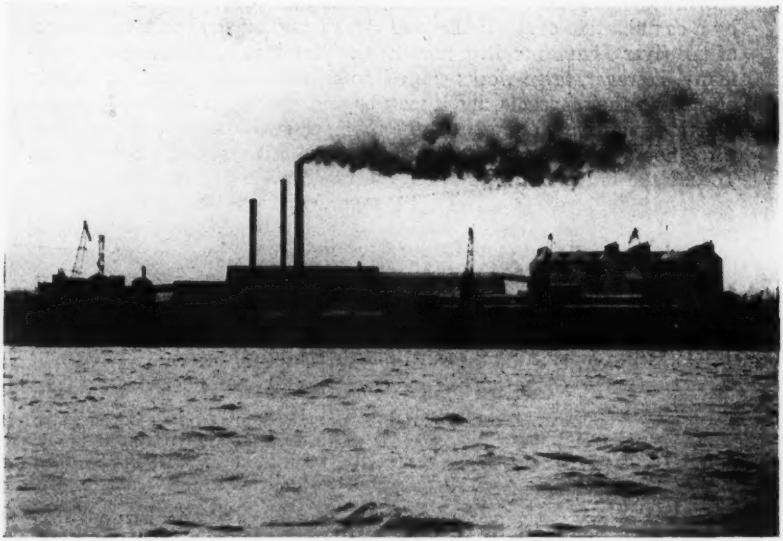


Fig. 1.—Bevans Works and Deep-Water Jetty.

Six truck-type units comprise the H.T. switchboard and control the two incoming feeders from the main sub-station, the H.T. side of the transformer, two feeders to the two main motor houses, and a feeder to the quarry giving a supply to an electric navvy. The 500-volt switchboard is built up of seven pedestal iron-clad units of the draw-out type, one unit controlling the L.T. side of the transformer, one the lighting transformer, and

the remaining five distributors to fuse pillars or boards from which the supplies to motors are taken.

In each of the two main motor houses are installed two 200 H.P. squirrel-cage motors, one driving a roughing mill and the other a line of finishing mills. The machines, fitted with centrifugal clutch pulleys and controlled by heavily-rated auto-transformer starters, totally enclosed and designed for operation by unskilled labour, effectively deal with the heavy starting duty imposed upon them. The roughing-mill motor is also fitted with barring gear driven through a special worm reduction gear by a high-torque motor, which facilitates cleaning out and overhauling the mill.

The chalk, quarried by a 3¼ cubic yard electrically-driven navvy fitted with a straight A.C. equipment, taking an average load of 150 K.W. and peak loads of 230 K.W., is conveyed to the washmill in trains made up of standard-gauge 10-ton trucks. Here the wagons run on to the electrically-driven tippler

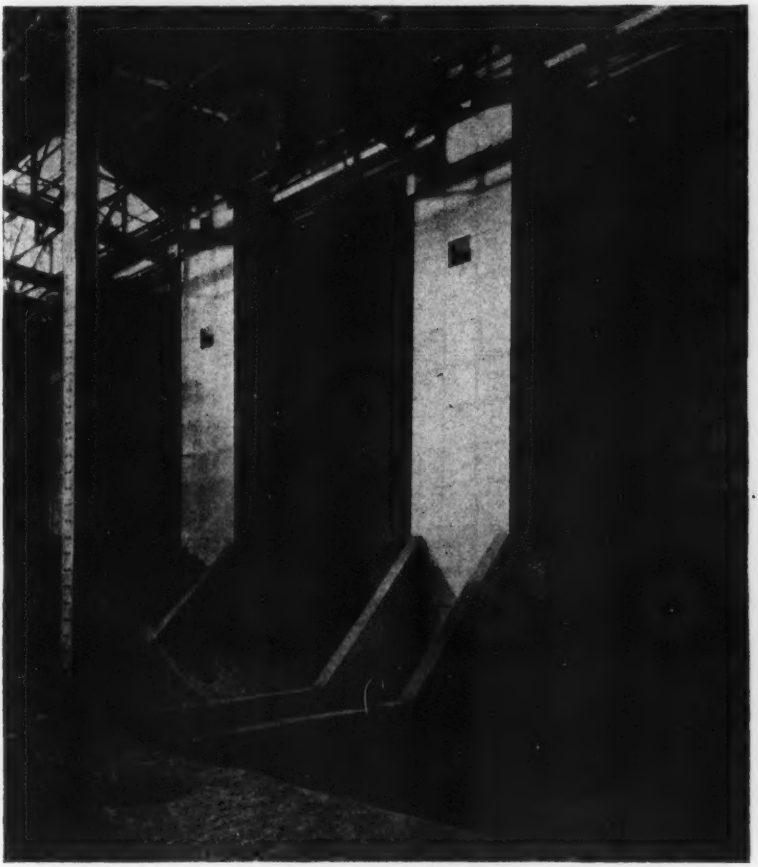
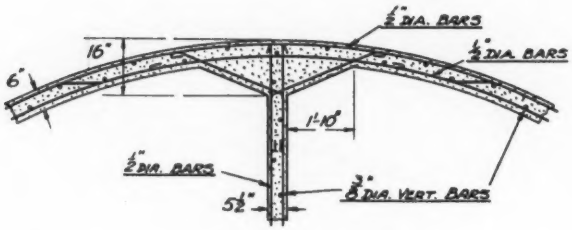
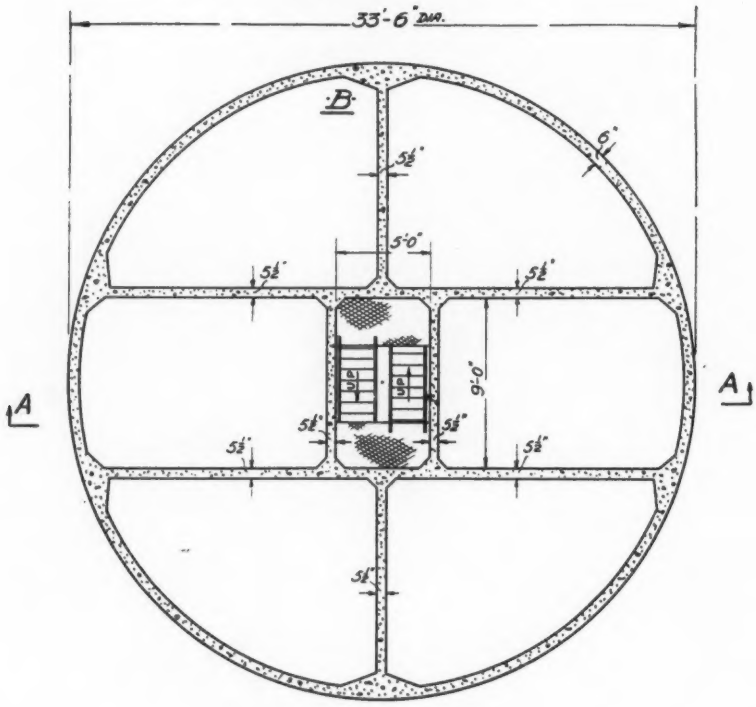


Fig. 2.—Clinker Hopper.

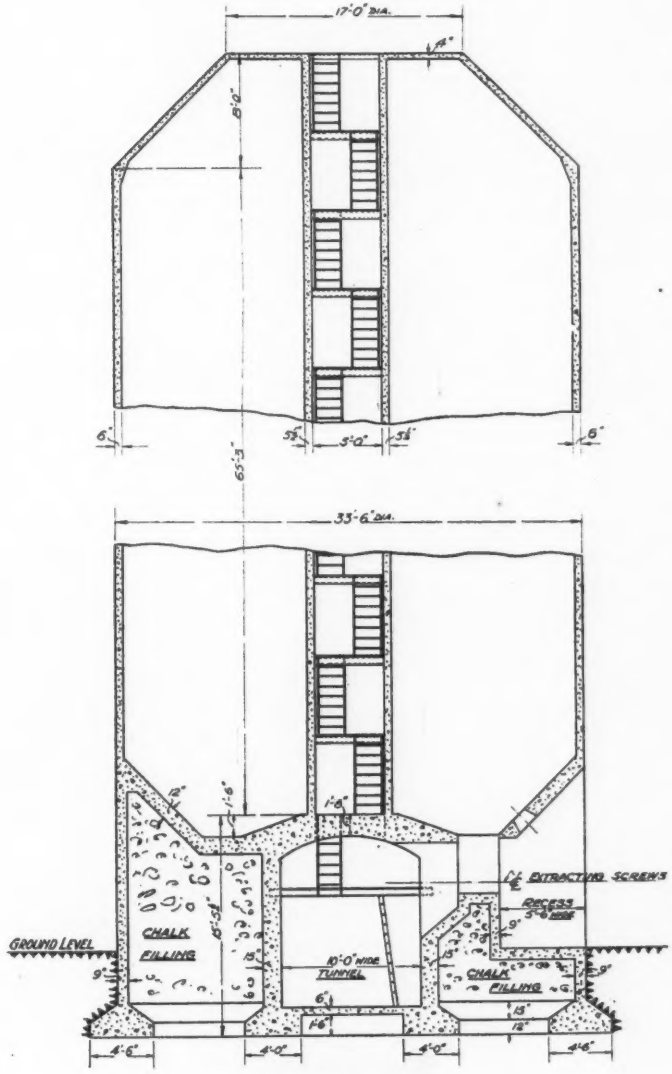


DETAIL AT -B-



SECTIONAL PLAN

Fig. 3.—Cement Silos.



SECTION ON A.A.

Fig. 4.—Cement Silos.

hoist, which is controlled by a fully automatic equipment; the operation of the starting button raises the truck about 40-ft. and then empties its contents into a hopper feeding the two roughing mills, afterwards lowering it to rail level. The tippler is fully protected by limit and emergency switches, and in addition a stand-by hand-controlled equipment can be put into operation by the throwing over a dual control change-over switch.

For a given quantity of chalk tipped into the washmill a certain amount of clay slurry is required. The slurry, stored in mixer tanks 30 yards distant from the washmills, is elevated and runs by gravity into the roughing mills. The elevator is driven by a 20 H.P. motor and is controlled by a direct switching contactor starter fitted with an adjustable timing device which can be set so that the elevator on operating the start button runs for a predetermined time corresponding to the amount of clay slurry required. The elevator is controlled at the tippler.

The clay slurry is obtained from the clay plant situated a mile from the main washmill, the power being transmitted to it at 3,000 volts by an overhead line. The transmission line is tapped about a quarter of a mile from the washmill for supplying a 75 K.V.A. transformer giving current at 500 volts to two electrically-driven centrifugal pumps. The line tapping is controlled by a pole-mounted oil-switch fitted with overload protection, whilst the pumps are controlled by automatic starters remote-operated from the washmills. The main units at the clay plant are three washmills and a line of pumps for pumping the slurry to the mixers situated near the washmills; each unit is driven by a 100-H.P. 3,000-volt squirrel-cage motor fitted with a centrifugal clutch and controlled by an auto-transformer starter. The equipment is simple and robust and gives no trouble although operated by very unskilled labour.

At the main washmill for pumping the finished slurry through the two pipe lines to the main works six three-throw pumps have been installed, each driven by a 50 H.P. squirrel-cage motor fitted with a centrifugal clutch coupling driving the pumps through reduction gears. The motor equipments are erected in line in the pump house whilst the starters, of the star-delta type, are mounted in a separate control room which also houses eight direct switching starters for 12-H.P. motors each driving a 66-ft. finished-slurry mixer. The separate control house for the control gear is a desirable feature on a washing plant.

Power is transmitted at 3,000 volts from the supply Company's sub-station, a distance of three-quarters of a mile to the main works, by six 0·4 sq. in. feeders drawn through a six-way earthenware duct, inspection and draw pits being provided every 200 yards. The feeders

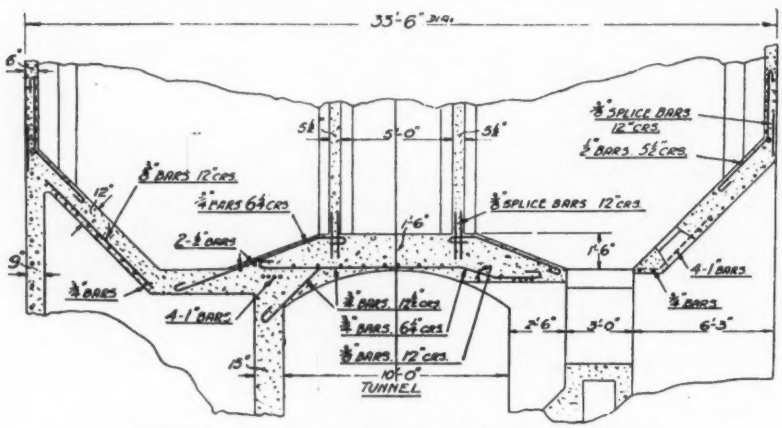


Fig. 5.—Cement Silos: Detail over Tunnel. (*See Fig.* 4.)

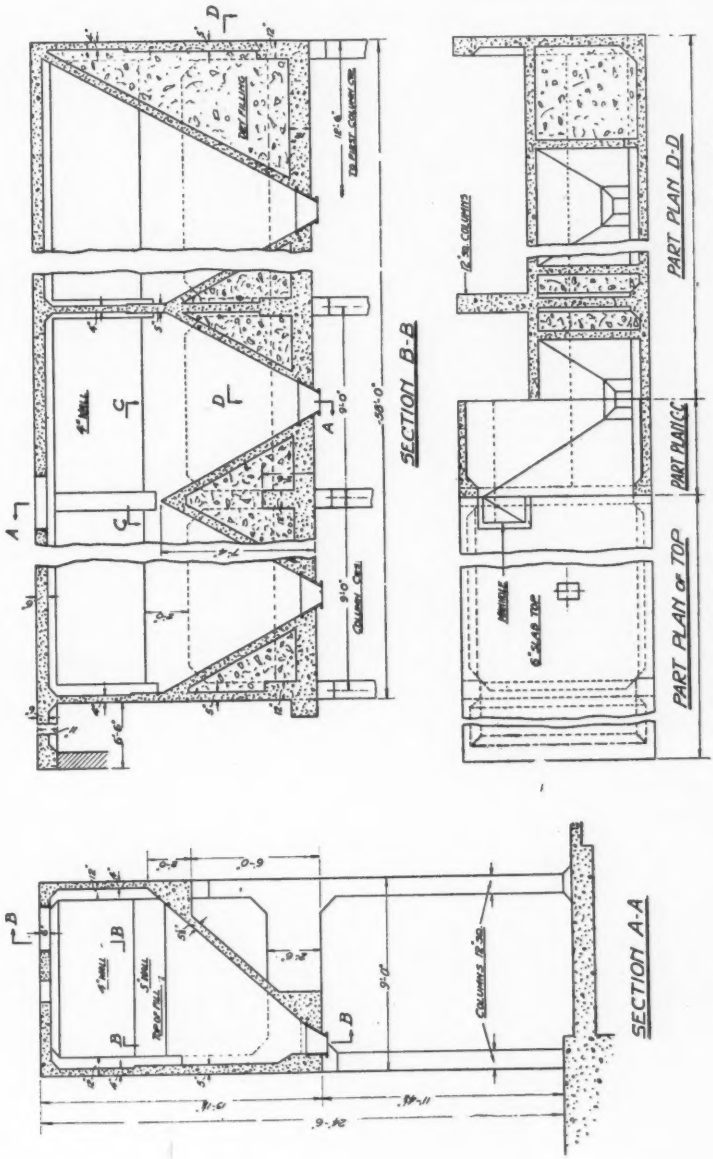


Fig. 6.—Raw Coal Hopper.

operate in parallel and feed on to the bus-bars of a 15-panel H.T. switchboard in the main works sub-station. The sub-station also contains five 750 K.V.A. 3,000/500 volt transformers, a 17-panel L.T. switchboard, and a 30-K.V.A. 500/110 volt lighting transformer bank with switchgear. The H.T. and L.T. boards are built up of truck type and ironclad pedestal units respectively, similar to those used at the washmill sub-station. The H.T. and L.T. switchboards are at each side of the sub-station facing each other with the transformers between them, the lay giving easy control of the distribution system which has been carried out on similar lines to that described at the washmill. Points of interest in connection with the sub-station are that the 3,000-volt incoming feeders are fitted with parallel protection induction type relays operating on the definite minimum-time-limit principle, and that the metering panel instruments include an indicating K.W. meter and power-factor meter showing the value and power factor of the factory load. These instruments are energised through pilot cables from potential and current transformers installed at the Supply Co.'s sub-station. A maximum demand alarm relay which operates a Klaxon horn when the load exceeds a pre-arranged figure is also provided.

In general the motor equipments call for no special comment. The six coal mills are each driven by a 75-H.P. vertical-spindle squirrel-cage motor fitted with a clutch pulley. The grinding mill motor house contains the motor units previously mentioned, which total 4,750 H.P., and the building is ventilated by clean washed air under pressure.

The Buildings.

Naturally the buildings, silos, washmills, and other structures are practically all constructed of reinforced concrete, and in addition there have been many minor applications of reinforced concrete, such as elevator towers, hot-air flues, etc., described in the following notes. Rapid-hardening Portland cement was used almost exclusively for all the reinforced concrete, and although a large proportion of the work was done in extremely cold weather it was nearly always possible to get a lift on wall work every day.

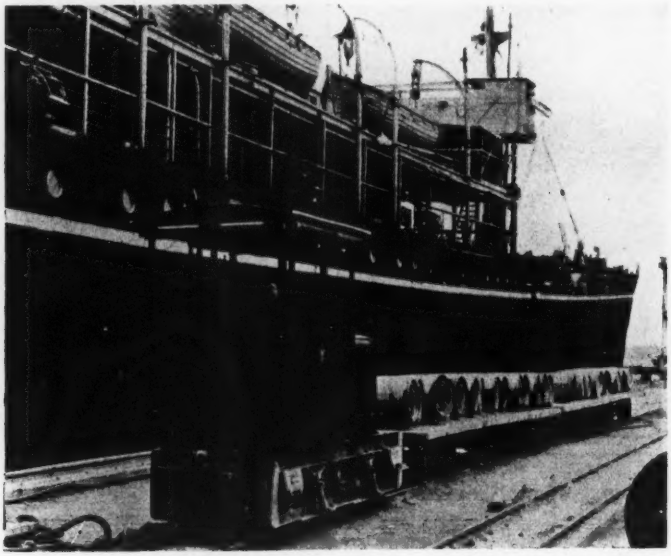


Fig. 7.—Petrol-driven Truck at work on Jetty.

Clinker Store.—One of the largest, and possibly the most interesting, structure is the clinker store, which is shown in *Fig.* 2. This is 173 ft. by 81 ft., and 47 ft. deep at its deepest point. It is capable of storing 15,000 tons of clinker.

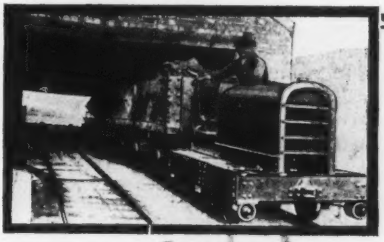
Cement Silos.—Most of the cement made at these works is stored in circular reinforced concrete silos, each capable of holding 2,000 tons of cement, see *Figs.* 3 to 5.

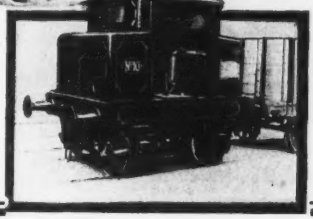
Each silo is 32 ft. diameter and 84 ft. high from ground level. Considerable space at the bottom is, however, taken up with the tunnel and cement extracting mechanism. Some of the silos are plain circular tanks above tunnel level, and the design of these is therefore comparatively simple. Other silos, however, are each subdivided into bins with a well and staircase up the centre. This is done in order to comply with customers' requirements when cement to a special specification is required, and holes are arranged at each landing of the staircase so that samples for testing purposes may be drawn from any bin and at any depth.

Coal Mill.—The coal mill is built entirely of reinforced concrete, and measures 65 ft. by 41 ft. by 32 ft. to the eaves. The construction consists essentially of 18 in. by 18-in. piers reduced to 18 in. by 12 in. at the top and spaced at about 12 ft. 6 in. centres. The space between the piers is filled in with reinforced concrete walls 6 in. thick. The columns, or piers, are each reinforced with four $\frac{7}{8}$-in. diameter rods with $\frac{1}{4}$-in. diameter lacing, and the walls have $\frac{1}{2}$-in. vertical rods spaced about 4 ft. centres with $\frac{3}{8}$-in. horizontal rods at a pitch of 12 in.

Raw Coal Hopper.—The coal mill contains a small reinforced concrete coal hopper used for the supply of coal to the grinding mills. Its capacity is about 60 tons. *Fig.* 6 shows the general outline. The hopper is 58 ft. long by 9 ft. wide, outside dimensions, and is provided with six outlets, one to each grinding mill. There is also a partition in the centre, so that one-half can be cleaned out, or a block cleared, while the other half remains at work. Two parallel rows of 12-in. square reinforced concrete columns support the hopper at about 12 ft. above floor level.

(*To be concluded*).





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Notes from Abroad.

France.

Societe des Chaux et Ciments de Toulon et du Var.—Under this title a new company has been formed to exploit quarries at Pomets, Toulon-sur-Mer. The head office is at Toulon, and the capital is 1,500,000 Frs. (£12,000).

Societe des Ciments de Mantes.—This company was formed in February of this year, and is now increasing its capital of Frs. 1,750,000 (£14,000) to Frs. 5,250,000 (£42,000).

S.A. des Chaux et Ciments Portland du Haut Rhin.—This concern is increasing its capital from Frs. 13 million (£104,000) to Frs. 15,600,000 (£125,000).

Germany.

A new factory is proposed at Grossburschla, with a daily capacity of 400 tons. The head office will be at either Cassel or Eisenach. This plant will be near the Westphalian border.

India.

The Dwarka Cement Factory, Baroda, purchased by the State in 1925 and remaining more or less closed since, has been sold to a new concern called The Okha Cement Co., Ltd., with a capital of Rs. 30,00,000 (£225,000). The plant and concessions have been sold by the Baroda State for Rs. 13,25,000 (£99,375), and the directors trust that the plant will be operating by January, 1929. The directorate includes Sir Purshottamdas Thakurdas, and Messrs. Mulray Khatan, Ambalal Sarabhai, F. E. Dinshaw, M. B. Nanavati. The old Dwarka Co. was capitalised at five million rupees and had a capacity of 100,000 tons per annum.

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